Trait cheerfulness modulates BOLD response in lateral cortical but not limbic brain areas - A pilot fMRI study

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Abstract: Having a good "sense of humor" is an important personality characteristic that significantly influences social communication and may represent an important coping strategy. To take things "with humor" does not only represent a state characteristic but also a personality trait that can reliably be assessed with questionnaires like the "state–trait–cheerfulness–inventory" (STCI) by Ruch [Ruch et al., Assessing the "humorous temperament": construction of the facet and standard trait forms of the state–trait–cheerfulness–inventory—STCI, Humor 9 (1996) 303–339]. Substantial inter-individual differences among study subjects are a key feature of almost all functional magnetic resonance imaging studies on higher cognitive functions. Usually, they are considered as "statistical noise" and are not recommended for the data analysis, although they can have a high intra-individual stability. However, a number of recent fMRI studies found robust correlations between inter-individual differences in BOLD response and personality traits such as extraversion. The aim of this pilot exploratory study was to localise regions where the BOLD response was predicted by "humor personality" scores. 10 healthy male subjects viewed funny or non-funny versions of Gary Larson cartoons while BOLD response was measured with functional magnetic resonance imaging (fMRI). Data were collected from the whole brain (28 slices, slice thickness 4 mm, 1 mm gap, TR = 3 s). SPM 99 software was used. A simple regression analysis with the sub-score cheerfulness from the STCI was applied. Higher cheerfulness in the STCI predicted brain activation in the right inferior parietal lobule (Tal X, Y, Z: 45, −77, 29), but not in limbic and prefrontal brain areas. We conclude that neural correlates of cheerfulness are correlated with BOLD response in lateral cortical rather than limbic brain areas. Likely the activated region is important for a readiness or tendency to be amused, whereas the regions previously shown to be activated in humor appreciation studies are related to the understanding of the joke and the emotional reaction.

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Trait cheerfulness modulates BOLD-response in lateral cortical but not limbic brain areas – a pilot fMRI study.

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Abstract:

Having a good "sense of humor" is an important personality characteristic that significantly influences social communication and may represent an important coping strategy. To take things "with humor" does not only represent a state characteristic but also a personality trait that can reliably be assessed with questionaires like the "state-trait-cheerfulness-inventory" (STCI-T) by Ruch (Ruch et. al., Humor 9 (1996) 303-339).

Substantial inter-individual differences among study subjects are a key feature of almost all functional magnetic resonance imaging studies on higher cognitive functions. Usually, they are considered as "statistical noise" and are not recommended for the data analysis, although they can have a high intra-individual stability. However, a number of recent fMRI studies found robust correlations between inter-individual differences in BOLD-response and personality traits such as extraversion.

The aim of this pilot exploratory study was to localise regions where the BOLD response was predicted by "humor personality" scores. 10 healthy male subjects viewed funny or non-funny versions of Gary Larson cartoons while BOLD response was measured with functional magnetic resonance imaging (fMRI). Data were collected from the whole brain (28 slices, slice thickness 4mm, 1 mm gap, TR=3 seconds). SPM 99 software was used. A simple regression analysis with the sub-score cheerfulness from the STCI was applied. Higher cheerfulness in the STCI predicted brain activation in the right inferior parietal lobule (Tal X,Y,Z: 45,-77,29), but not in limbic and prefrontal brain areas.

We conclude that neural correlates of cheerfulness are correlated with BOLD response in lateral cortical rather than limbic brain areas. Likely the activated region is important for a readiness or tendency to be amused, whereas the regions previously shown to be activated in humor appreciation studies are related to the understanding of the joke and the emotional reaction.

Introduction

Having a good "sense of humor" is an important personality characteristic that significantly influences social communication and represents an important coping strategy to manage everyday hassles [9] and depressive symptoms [11, 12, 44]. Cheerfulness represents an important domain within the “sense of humor”. Cheerfulness as a characteristic of personality does not only represent a state characteristic (we are differently “cheerful” in different social situations), but a personality trait as well. The trait of “cheerfulness” is associated with a permanently reduced threshold to start laughing and become exhilarated [29]; furthermore in humans high on the cheerfulness-trait scale, a much stronger stimulus is needed to induce sad moods than in humans with low trait exhilaration [31].

Trait cheerfulness can be reliably assessed using the trait part of the “State-trait-cheerfulness inventory” (STCI-T) by Ruch [32], English version [33]. The State-Trait-Cheerfulness-Inventory (STCI) is an instrument used to operationally measure the qualities of cheerfulness, seriousness, and bad mood. The trait version of the instrument exists in German and English versions; it was validated in a population of more than 1000 subjects [32]. Recently a number of studies have used this instrument to describe the personality trait “cheerfulness” and its relationship to other personality traits [38, 46].

Substantial inter-individual differences among experimental subjects are common sources of statistical scatter in functional magnetic resonance imaging studies and psychological investigations. Whenever “higher” cognitive functions, such as reading complex sentences, understanding cartoons or evaluating social situations are investigated, marked inter-individual differences are regularly detected among the datasets of the individual subjects. These inter-individual

differences are usually interpreted as random “statistical noise” and are not commonly investigated further [5], although they can have a high degree of intra-individual stability [21][26]. This is problematical inasmuch as functional magnetic resonance imaging (fMRI) methodology is increasingly used to demonstrate subtle differences between populations, for example groups with different expressions of a single gene [16, 19], presence or absence of a history for a psychic trauma [45] or high risk populations for a specific disease [40].

A number of recent studies have demonstrated that personality and character traits may explain a relevant amount of the variance within fMRI datasets. Although using relatively moderate numbers of study subjects, these studies exhibited astonishingly robust correlations between BOLD-response in distinct brain areas and psychometrically measured personality traits [1, 10, 20]. For example, a stable correlation between BOLD response and the character trait “Eysenck-Extraversion” could be demonstrated in the amygdalae and limbic brain areas in several fMRI studies [1, 5-7]. Extraversion is a personality trait that is significantly associated [27, 28], yet not identical with cheerfulness. Notably, some of the regions found to be activated in these studies on personality traits were also found to be activated in brain imaging studies on humor appreciation. A number of studies have investigated the neural correlates of humor appreciation with functional magnetic resonance [3, 13, 14, 22, 24, 25, 35, 39, 43] and PET [17] (see [41] and [43] for an overview). The regions shown to be activated during humor appreciation in these studies included both cortical regions (such as the left inferior frontal gyrus [25, 43], medial frontal [13], anterior [13, 14, 43] and posterior temporal [13, 14, 35] gyri) as well as subcortical nuclei (such as the caudate [14] and nucleus accumbens [17]) and limbic structures (such as the hippocampus [14] or amygdalae [24]).

In the investigation described below, we re-analysed data from a previous study from our workgroup [43] in which healthy male subjects watched funny cartoons, while the BOLD response was measured using functional magnetic resonance imaging. In a subgroup of this sample, the “trait cheerfulness” was assessed using the German state-trait-cheerfulness inventory [33] and we correlated individual’s scores on this questionnaire with the subjects’ BOLD-responses while watching Gary Larson cartoons. The aim of this exploratory study was to determine whether or not the location of regions of BOLD responses could be predicted by results from "humor personality" scores. Our hypothesis was that trait cheerfulness predicts brain activation in either limbic or medial / lateral prefrontal brain regions.

Materials & Methods

Data from a previous study on humor appreciation [43] were re-analysed. 10 right-handed male subjects without history of or current neurologic or psychiatric disease were included in the analysis. Three subjects from the previous investigation were not included because no STCI-data were available. Subjects were recruited by advertisement.

Stimuli consisted of nonverbal (i.e., no captions) cartoons by a single cartoonist (Gary Larson) projected onto a screen that was visible to the subjects from within the MR apparatus. These “funny” cartoons were presented at random intervals during a baseline state in which the subject was shown very similar “non-funny” cartoons. Imaging was performed on a 1.5-T Scanner (Siemens, SONATA). Data acquisition and pre-processing are described in detail in our previous paper [43].

To investigate the influence of the humor-related personality characteristics a simple regression analysis of SPM data was used. In this type of analysis, each single voxel in the brain is individually examined with respect to whether the inter-

individual variability of a variable is correlated with the inter-individual variability of the BOLD-response in this voxel. The result of this analysis is a brain-map which depicts the voxels with which there is a significant correlation between the variables. Due to the explorative character of our pilot-study, we chose a liberal threshold of $p<0.001$ uncorrected for our analysis. Differential contrasts from each individual for watching funny and not-funny cartoons against low level baseline were used. Separate tests were performed for a positive correlation (i.e., the higher the score of the individual subject in the cheerfulness questionnaire is, the stronger the BOLD response) and a negative correlation for the "cheerfulness" score of the STCI-T (i.e., the higher the score of the individual subject in this personality questionnaire is, the weaker the BOLD response).

After the scanning session, subjects rated all stimuli on a seven point likert-scale (0 = not funny to 6 = very funny). A score of >= 3 was defined as funny cartoon.

Results

Whole brain analysis for the contrasts of watching funny versus not-funny cartoons have been published previously [43]. The exploratory analysis for the influence of having a "cheerful personality" showed one cluster of activation in the right inferior parietal lobule (Tal X, Y, Z: 45, -77, 29, Z-value 4.01, $p<0.001$ uncorrected) with the positive correlation. A negative correlation was present in the cingulate gyrus (Tal X, Y, Z: 18, 7, 27, Z-value 3.57) and the fasciculus occipito-frontalis (Tal X, Y, Z: 18, 7, 27, Z-value 3.7).

[insert table 1 about here]

[insert figure 1 about here]

In the post-hoc rating of the cartoons , subjects rated between 0 and 74 cartoons as funny (mean value 19.3, SD 22.5). However, in our pilot sample no significant correlation was found between the number of funny cartoons and trait exhilaration.

Discussion

We used functional magnetic resonance imaging to detect brain regions in which the inter-individual variability in the cerebral BOLD response while watching funny and non-funny cartoons is correlated with the inter-individual variability in trait-cheerfulness measured with the state-trait-cheerfulness inventory (STCI, [33]).

A significant positive correlation between the trait “cheerfulness” and the BOLD-response was present in one cluster of activation in the right inferior parietal lobule. This brain area belongs to the semantic association areas and its left hemisphere equivalent plays an important role in integrating semantic language content into language context. It is located at the end of the superior temporal sulcus and is approximately equivalent to Brodmann´s area 19. It has also been reported to be activated in a recent fmri study on processing of noverbal cartoons [35]. We had no a- priori hypothesis regarding the fasciculus occipito-frontalis and anterior cingulate, where a negative correlation was found . This result may be an artefact. It is however interesting, that Habel et. al [15] found an activation in this brain region during sadness provoking stimuli [10,15].

Our results suggest that among individuals there are inter-individual differences in the amount the inferior parietal lobule is involved in the process of understanding cartoons. This result seems plausible: this brain region plays a role in resolving incongruities - and resolving incongruities is a key element in the process of humor appreciation [27, 29, 34, 42] inasmuch as incongruity is an essential ingredient of nearly all jokes [8]. Furthermore there is, as well, evidence from

investigations in the realm of personality psychology that intolerance of amibiguity is related to personality traits associated with humor [30]. For example, Ruch and Hehl (1983) investigated the relationship between intolerance to ambiguities [4] and type of preferred humor in 134 male subjects [30]. They concluded from their results that the individual “sense of humor” may depend on the way an individual deals with ambiguous uncertain stimuli [30]. The activations found in our study could represent a neural basis for this, a speculation that would need to be further evaluated. It is, however, notable in this context, that robust correlations between brain anatomy in the association cortices and certain personality variables have been demonstrated for other personality traits as well [18].

Surprisingly, no significant interaction between the trait “cheerfulness” and the limbic system activation was observed in our study. Instead, activation was present in lateral cortical brain regions. We conclude from this pattern of activation that exhilaration as a personality trait is correlated with cortical rather than subcortical brain regions. This finding is in contrast to research on certain other personality traits, in particular to findings on “extraversion” and “neuroticism”, which both showed robust correlations with BOLD response in limbic brain areas such as the amygdalae [5]. Activation in limbic brain areas was detected in most imaging-studies on humor appreciation as well [14, 17, 22, 24, 43].

Our hypothesis is that limbic brain activation is associated with humor appreciation and associated with the resultant feeling of exhilaration, whereas activation in the parietal lobule is associated with being a humorous, “exhilarable” person who enjoys ambiguity.

Several factors limit the interpretation of our study. First, the number of 10 experimental subjects is relatively low, so that our investigation has the character of a pilot study and future research should test the validity of our findings in a larger

number of subjects. On the other hand, previous functional magnetic resonance studies have shown stable effects on personality traits with roughly the same number of subjects [1, 10, 20]. Another possibly confounding issue is that we did not apply extensive test batteries on other personality variables. This point may be important since previous research with fMRI has demonstrated effects of other personality traits of subjects looking at funny cartoons [23]. Most studies on fMRI correlates of personality, however, have demonstrated robust correlations with “extraversion” in limbic brain areas such as the amygdalae, a region in which no correlations with STCI scores could be demonstrated in our investigations. We thus consider it unlikely that the character trait “extraversion” alone explains the results of our study.

Only one further functional imaging study has, as of yet, investigated the neural correlates of personality during humor appreciation. Mobbs and colleagues [23] investigated the influence of the personality traits: “extraversion-introversion”, “neuroticism” and “sense of humor” on the BOLD-responses in subjects viewing funny cartoons. The strength of ”extraversion – introversion”, but not the score of the “sense of humor” questionnaire was significantly associated with BOLD response in cortical brain regions and the amygdalae. Several factors may contribute to the difference between our study and theirs. First, different measurement tools of “humor personality” were applied: whereas Mobbs et al. used the 21-item “Sense-of-humor-questionnaire” [36, 37], we used the 60-item “State-Trait-Cheerfulness-Inventory” [32]. Gender differences of the subjects might also explain some differences in the results of the two studies, since gender is known to influence BOLD response to funny cartoons [2]. Only male subjects were included in our investigation, whereas Mobbs et al. included both male and female subjects. Another possible, but in our estimation less probable explanation for the

differences between the studies might be found in differences in the stimulus material applied and the baseline condition used in the two studies. Further research should thus specifically address these issues.

We conclude that inter-individual differences in the character trait of “cheerfulness” could be demonstrated in semantic-association areas – but not in limbic brain areas in our study using functional magnetic resonance. The BOLD activation in the inferior parietal lobule of the right hemisphere correlated with the trait “cheerfulness”. This activation might be associated with a general readiness or tendency to be amused by jokes, whereas the regions previously shown to be activated in humor appreciation studies seem more likely to be related to the understanding of individual jokes and the momentary emotional reaction of exhilaration.

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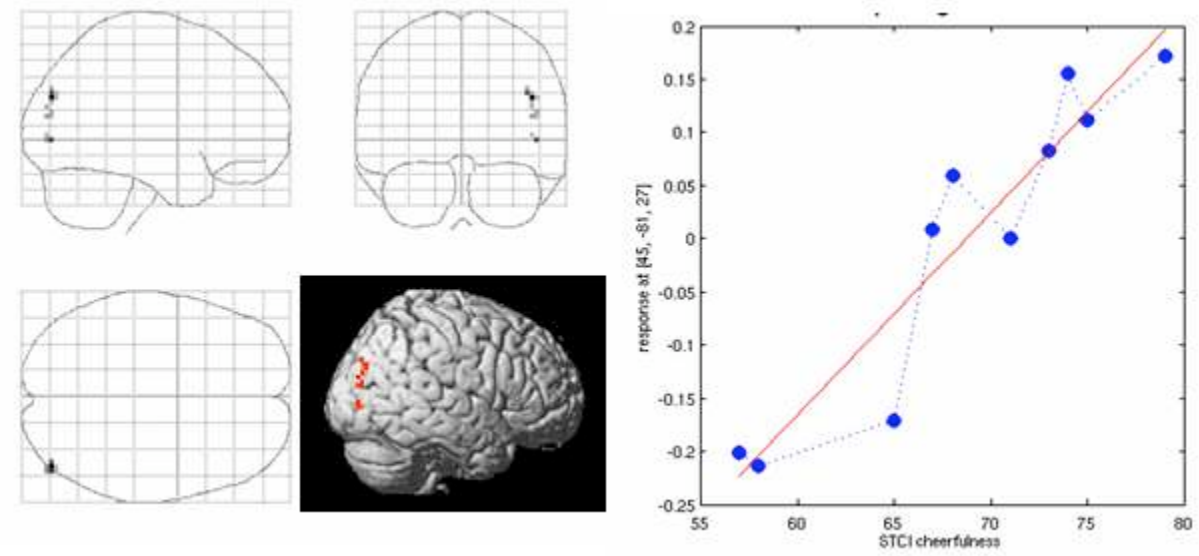
Table 1: correlation between STCI-T-cheerfulness and BOLD response during watching cartoons (P<0.001 uncorr., extent treshold 5 voxels)

	Cerebral area	Brodmann area	hemisphere	Tal X	Tal Y	Tal Z	number of activated voxels	Z-value
positive correlation								
cheerfulness	inferior parietal lobule	19 / 39	R	45	-77	29	7	4.01
negative correlation								
Cheerfulness	Fasciculus occipito-frontalis		R	18	7	27	13	3.7
	cingulate gyrus	24/32	R	12	28	26	10	3.57

Picture 1



Association of brain activation during watching funny cartoons and trait cheerfulness measured with the STCI: positive correlation in the right inferior parietal lobule ($p<0.001$ uncorrected).